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Product Mix Development: Strategy Making at the Enterprise Level

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**PRODUCT MIX DEVELOPMENT:
STRATEGY MAKING AT THE ENTERPRISE LEVEL**

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Collaborative paper series on
Comparative analysis on application of decision support systems in R & D decisions

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
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COLLABORATIVE PAPER SERIES ON COMPARATIVE ANALYSIS ON APPLICATION OF DECISION SUPPORT SYSTEMS IN R & D DECISIONS

This series of papers are a product of collaborative research coordinated through IIASA's Management and Technology Area. The collaborating institutions are Hungarian State Office of Technical Development (personnel: Anna Vari, Janos Vecsenyi, Laszlo David); Decision Analysis Unit, Brunel University, England (Personnel: Patrick Humphreys, Lawrence D. Phillips); All-Union Research Institute of Systems Studies, USSR (Personnel: Oleg. I Larichev).

The papers report case studies prepared by the personnel from the collaborating institutions based on their own, and their colleagues' work in their own institutions. They worked together as a team in developing the methods for the analysis of these case studies which are described in the first paper in the series.

IIASA provided support for this work through its telecenter for communication between the investigations, and provided facilities for short term meetings between the investigations at IIASA for development of case studies and their comparative analysis. Particular MMT staff were Ronald M. Lee, Nora Avedisians, and Miyoko Yamada, who is the editor of this series.

A summary of this comparative analysis, based on the first four case studies in this series was presented at the IFIP/IIASA Conference on *Processes and Tools for Decision Support*, Laxenburg, Austria, July, 1982.

The papers in this series are

1. Humphreys, P.C., A. Vari and J. Vecsenyi: Methods for analyzing the effects of application of Decision Support Systems in R & D decisions (CP-82-69).
2. Vari, A. and L. David: R & D planning involving multicriteria decision analytic methods at the branch level. (CP-82-73).
3. Vecsenyi, J.: Product mix development: strategy making at the enterprise level. (CP-82-74).
4. Larichev, O.I.: A method for evaluating R & D proposals in large research organizations. (CP-82-75).
5. Humphreys, P.C. and L.D. Phillips: Resolution of conflicting objectives in evaluating R & D projects involving collaboration between industry and higher education. (CP-82-xxx, forthcoming).

The paper presented at the IFIP/IIASA conference will be published as Humphreys, P.C., O.I. Larichev, A. Vari, and J. Vecsenyi, Comparative analysis of decision support systems in R & D decisions, in H.G. Sol (ed.), *Processes and Tools for Decision Support*, Amsterdam: North Holland, 1982. Another study in this series was published separately as L.D. Phillips: Requisite decision modeling: a case study. *Journal of the Operations Research Society*, 1982, 33:303-311.

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CONTENTS

PRODUCT MIX DEVELOPMENT: STRATEGY MAKING AT THE ENTERPRISE LEVEL

J. Vecsenyi

I. INTRODUCTION

This case study is presented with the aim of providing an insight into how a decision support system (DSS) was applied in two cases at a Hungarian chemical works (CW) for formulating development and production strategies.

R & D strategy-making is quite often based on the assessment of R & D *proposals*. In this case, these are new ideas and previous R & D results to be evaluated. Very rarely, it occurs that R & D strategy-making is based on assessment of actually manufactured products. This was, however the case in strategy-making in the CW during the rounds discussed in this paper. Here, R & D strategy was formulated on the basis of analyzing the actual mix of products being fabricated (the product-mix), revealing the weak points and requirements for development of the individual products in the mix. The same analysis was also considered appropriate for showing what the preferred products should be when completing production plans. The procedure used did not focus on the assessment of alternative R & D projects as such, only their components, i.e., preferences between products for development and production. This, of course, does not mean that the assessment of the R & D projects themselves should be omitted from strategy making. However, the DSS applied here did not cover this area.

The cases described here constitute two rounds in the overall strategy making decision process at CW. (A discussion of rounds and stages within rounds is given in Humphreys et al. 1982a.) The DSS used in each of the rounds was seen by both decision makers and consultants (analysts) as a procedure generating multi-attribute utilities of the product-mix (MAU-P) based on individual and group work, supported by computer programs. For describing DSS several definitions have been proposed. Here we follow the wider definitions given by Keen and Hackathorn (1979) and Humphreys et al. (1982b).

These view the "system" as a whole including both people and automated support techniques, which can be developed dynamically, starting from a situation which is initially well structured. Repeated application is one of the crucial factors in DSS development, as more information about structure is available in later applications, given appropriate analysis of previous rounds in which the DSS has been applied. In the cases described here, there were two applications of DSS, the first in the first round, of strategy making, starting in 1979, and the second one in the next round, which started in 1981.

II. THE PROBLEM SITUATION

Round 1

At the time of the first round the situation of the enterprise (a chemical works producing plastic articles, pesticides, intermediaries used in the pharmaceutical industry, and other organic and non-organic chemicals) was uncertain. The rate of development of the firm had decreased, it had economic troubles, the ministry wanted to reduce the autonomy of the CW by fusing it with a larger enterprise. But as a last chance new top managers were invited to help in solving the problem of the company by making a strategy for development. One of these decision makers responsible for the success and survival of the firm initiated the analysis of the problem by decision analytic tools. In a postgraduate course on management science at the Department of Industrial Engineering, Technical University of Budapest, he had become familiar with multiattributive utility theory and its practical use. He believed that this new method would be better than the traditional cost-effect, market position evaluation.

The problem was defined at the outset of the round on the selection of the products to be developed, maintained or omitted from the product mix. This, however, was only part of the overall R and D policy making for CW, which was to determine the development and production strategy for the next one to five years. The method of decision analysis as well as the supporting computer software were developed by a team of decision analysts (the *consultants)* from the Bureau for Systems Analysis of the Hungarian State Office for Technical Development, the Technical University, Budapest and Management School, Ministry of Industries, Esztergom, Hungary.

Round 2

Two years later there was a second round in the process. The mode of initiation of the analysis, the definition of the problem and the method of use of DSS remained the same. However, at that time the situation of CW had improved. In the interim period between the rounds the firm has gradually started to develop, its economic state had stabilized, and its independence had been assured. Consequently, the motivation of the participants in the round for DSS had changed. In Round 1, decision makers perceived the use of DSS as one of the tools of survival but in Round 2 DSS was perceived by decision makers only as a good help for re-evaluating the previous strategy based on the results of DSS in Round 1.

The composition of the participants in the round also changed. In Round 1 representatives of state authorities and of related organizations (e.g., foreign trade companies, association of chemical enterprises, etc.) were also involved in the process of DSS. However, in Round 2, only internal experts were involved. In Round 1 the involvement of external representatives was one of the ways of getting their benevolent support in helping the survival of the CW. They thus played the role of ***facilitators*** in the decision making processes in this round. In Round 2 there was no need for such explicit participation of external facilitators.

In the following sections we shall consider the stages in Round 1 in detail, and then give an overview of Round 2.

III. ROUND 1

A. Responsibility and Motivation of Parties Involved

The *decision makers* in the round (the board of top level managers) were responsible for the determination of company strategy. However, they knew that they also had to "set an example" to decision makers at a higher level (in the ministry) if the company was to survive as independent. At this higher level, they acted as *proposers*, recommending their methods of analyzing the problems of the company as the basis for *their* good strategic planning (as against the alternative of being fused as a component into some other strategic plan). Hence their motivation was quite complex, being oriented towards three goals:

(i) rationalizing their decision by basing them on more reliable information;

(ii) getting the collaboration of lower level managers in carrying out the strategy (they were new in their positions);

(iii) having a tool for convincing higher level authorities (the ministry) by "setting an example" to them by solving the company's problems by using up-to-date tools (this served the decision makers in their *proposer* role).

The *experts* involved in this round were middle level managers and key figures in specific economic and technical fields. They were responsible for providing reliable and detailed information about several, or all of the products of the company on several or all of the attributes considered in the decision analysis, according to their perceived expertise. In Round 1, representatives of state authorities, foreign trade companies, and the association of chemical enterprises responsible for the affairs of the company were also involved as *external experts*. But they were involved only at stage 2 in the round (see below), when they were invited to assign weights to the attributes.

The *internal experts* were motivated by the possibility of

(i) influencing the decision making process by using their information;

(ii) explaining their views and preferences;

(iii) convincing the new managers of their readiness for collaboration.

The motivation of the experts was not homogeneous and explicit. The external experts collaborated willingly, (of 18 external experts invited to participate in the attribute weighting procedure, 15 accepted the request). The challenge for the *external experts* was provided by the novelty of how their opinions were requested. This was by a formal letter written by the director of the CW. The letter contained a questionnaire asking for their opinion on the importance of each main attribute expressed (i) by ranking all attributes, and (ii) by rating each main attribute on an interval scale ranging from 0 (no importance) to 10 (extreme importance). For making their rankings and ratings they received guidelines containing examples.

The team of decision analysts, acting in this round as outside *consultants* were responsible for delivering methodological and managerial support for the decision making process. Consultants were motivated by two goals:

(i) developing and testing new methods for real life problem solving

(ii) proving that the information of the managers and experts can be effectively used in an organized communication process compatible with DSS.

B. The Function of the Expected Results

The "function of the expected results" implied something different for everybody concerned with the decision making process in the round. Humphreys et al. (1982a) gives a general discussion of active views of effects of DSS that participants may hold (see their Figures 1 and 2). In our case, the most important function of expected results perceived by the *decision makers* was to have an insight into the product mix on which their strategy could be viewed.

For *the experts*, the most important effect expected from the application of DSS was the communication of information. For *decision analysts*, the most important factor was the possibility for feedback about the appropriateness of their method.

C. Stages in the Analysis

The DSS used in the round was seen by both *decision makers* and *consultants* (analysts) as a procedure generating multiattribute utilities of the product-mix (MAU-P) based on individual and group work, supported by computer programs. This DSS supported the first four of the five stages outlined below. The five stages were:

Stage 1: Exploration of attributes

Stage 2: Weighting of attributes

Stage 3: Assessment of alternative products

Stage 4: Computation of multiattribute utilities of products in the mix

Stage 5: Strategy making

Stage 1. Exploration of Attributes

Previously, the Hungarian State Office for Technical Development and the State Planning Office had published a set of technical-economic criteria for evaluating product-mix and production structure (OT-OMFB 1978). This contained attributes appropriate for use in ***branch- level*** decisions. For this reason these sets of attributes needed to be adapted first for assessing products (rather than production structure) and secondly, for use in the actual CW application.

In the first step of adaptation, a list of ten main attributes and 56 subattributes for evaluating products were initially compiled by post-graduate students in industrial engineering. In the second step, this set of attributes was discussed and modified by 30 leading executives of CW resulting in a revised specification comprising 70 subattributes, while the main attributes remained unchanged (except for changes in interpreta-tion).

When selecting attributes, we faced a problem frequently present in these cases, i.e., with how many attributes should we work? If several attributes are used, the picture will be differentiated but the aggregation will be more difficult. If only a few attributes are used, the diversity of the evaluation is reduced, but the reliability of aggregation is increased or at least appears to increase. The pitfalls revealed here have been reported in a previous paper (Vari and Vecsenyi 1982).

In our case we adopted the following compromise: ten main attributes were selected, each being further differentiated with a set of subattributes to aid the interpretation of the main attribute.

The 10 main attributes were:

E1 — the "up-to-dateness" of the product

E2 — the significance of the product

E3 — the market and trade situation

E4 — technical level of production

E5 — dimension of the production

E6 — raw material and energy supply

E7 — man power requirements

E8 — management needs

E9 — necessity for development

E10 — profitability

Each main attribute was verbally interpreted and the relative subattributes were listed. As an example, this listing is presented below for attribute E2.

> The ***significance of the product*** shows the importance of the given product for the manufacturing company rather than buyers and traders.
>
> The subattributes to be considered are

E21 — ratio of the product production to total production

E22 — role of the product on the context of the internal production

E23 — ratio of the product production in home and international collaboration.

We are aware that two pitfalls have to be avoided when setting up descriptions of main- and subattributes in this way

(i) Having too many subattributes increases the uncertainty of characterization of the main attributes because we do not know which subattributes are influential.

(ii) Too few subattributes may make their use superfluous since the characterization of main attribute on its own may form a sufficient basis for evaluation of products on it.

In defining attributes, there may also be problems stemming from conflicts in means-ends relationships.

For example, in the 10 attributes incorporated in the DSS, there is a mixing of means-ends and condition characteristics (e.g. *up- to- dateness of the product* (E1) could be an ends but also the means in achieving *profitability* (E10), while the *man- power requirement* (E7) is an example of condition attribute). This problem is discussed further in Vari and Vecsenyi (1982). In "text-book" accounts of multi-criteria decision making attributes are generally generated from the objectives of the decision makers. While it is known that it is often difficult to get an access to the decision makers' objectives and attributes, it is generally assumed that the attributes can always be deduced from the objectives. If it is not possible to find more closer contact with top level decision makers, the usual ploy is to suggest that attempts should be made to find out their objectives and attributes by different methods (e.g. through constructing Rand's decision score cards as used in the Polano project, see Goeller 1977). In our case the procedure actually employed was just the opposite of this, viz:

(i) The consultants adopted the above-mentioned set of attributes and the inherent goal-system published and recommended by the central organs.

(ii) This set of attributes was "translated into their own language" by more than 30 top and senior managers.

(iii) The implicit and explicit objectives of the company were related to the set of attributes by decision makers.

An example for of one of the forms of relating objectives to a particular attribute is as follows:

> "According to the *technical level of production* the related company objectives are those concerning the production of intensive technology with high productivity and a great variety of convertibilities".

Naturally, the compiled attributes were not viewed as being equally important, and so the next stage involved taking into account the differential importance of attributes by determining relative weights.

Stage 2. Weighting of Attributes

In this stage CW managers determined company objectives and requirements related to criteria, so that attributes of products related to these criteria could be evaluated. In support of this, the *consultants* (the analysts who designed the DSS) organized a training course for the participants on the methods of weighting attributes and assessments of the products and on the procedure of DSS.*

Here, separate vectors of weights were elicited from all 78 participants in this stage in the round (five top level executives, 38 medium level executives, 20 internal and 15 external experts). The director of CW also asked 15 external experts at the "higher level" discussed earlier (members of the supervising committee and representative of their respective supervisory committee at the ministry) to determine importance weights for the principal criteria. (Recall that at this higher level the director acted as *a proposer* rather than as a decision maker.)

The consultant analysts used clustering techniques to *compute* pooled vectors of weights of the participants in the round. The automatic clustering was based on a computer program which considered the degree of concordance between clusters of vectors of weights. Kendall's coefficient of concordance was used as the index in determining clustering. Approximately ten "opinion groups" (middle level clusters) were identified through this clustering technique. The executives of the company discussed the similarities and differences between the results for the various opinion groups, and agreed that the model should be simulated using (separately) the vectors of weights from three groups:

(i) top executives of the company (coefficient of concordance=58.9%)

*This followed from the consultants' goals from the round, which were quite different from the motivations of the decision makers, viz: (i) developing and testing new methods for real life problem solving, (ii) proving that the information of the managers and experts can be effectively used in an organized communication process compatible with DSS and (iii) minimizing the faults on the basis of previous experiences.

(ii) the opinion group of 14 decision makers clustered at the intermediate level in the cluster analysis of weights vectors for all 78 evaluators whose individual weights demonstrated the highest degree of concordance (92.8%), and

(iii) the weights for the group of all 78 evaluators (concordance=59.9%).

The results of ranking and rating of attributes, aggregated for each of the three groups are shown in Table 1.

The value system of top managers (11 members) reflected by ranks and weights is, in this sense, definitely more "forward-looking"* than that revealed in the vector of weights averaged over all evaluators. This is

Table 1. Ranks and weights of the attributes for each of the groups chosen by CW executives as the basis for simulation.

Groups	Top managers		Group with the highest degree of concordance		All 78 evaluators	
Attributes	Ranks	Weights	Ranks	Weights	Ranks	Weights
E1	3	6.64	4	6.00	4	5.72
E2	4	6.00	3	6.54	3	5.83
E3	*1*	*7.18*	2	7.92	2	7.46
E4	5	5.55	6	5.00	6	5.06
E5	6	4.55	8	3.23	8	4.13
E6	7	4.50	7	4.62	5	5.41
E7	8	4.18	9	2.85	7	4.67
E8	10	0.73	10	1.38	10	2.01
E9	9	2.27	5	4.08	9	2.91
E10	2	7.09	*1*	*9.08*	*1*	*8.09*

*Top managers often attempt to achieve the *satisfactory* level on a particular criteria (level of profit, production, output, etc.) in many cases. Such managers can be characterized as "backward-looking"; they are quite conservative and do not take many risks. In the opposite case, there are top managers who have to produce results which are liable to be risky but may however, also be indispensable for survival. These kinds of managers can be characterized for "forward-looking".

shown by their preference of the market and trade situation (E3) as well as by that of the up-to-dateness of the product (E1). This group can be called the *market- oriented group*.

The group with the highest degree of concordance (14 members) consisted partly of top and middle managers and partly of external experts. It was striking in this group that the necessity for development (E9) was considered more important than the other two groups. Since here *profitability* (E10) came first, we may call this group *profit- oriented* group.

According to the value system of all participants (78 members), it can be agreed that, here as well as in the previous group, profitability was ranked first. It can be assumed that, in this case, too, as in the group with the highest degree of concordance, in the minds of the evaluators, this attribute is reflected as a common factor. Otherwise, the overall value system appears rather conservative.

This model as applied, was able to take the different opinions into consideration by evaluating products under each of the alternative weighting schemes. Consequently, there was no need to unify the revealed divergence of opinions either by exercise of power or by seeking consensus.

Stage 3. Assessment of the Alternative Products

Assessment of 46 alternative CW products were made by the same internal 63 participants as in stage 2 (no external experts were involved), using a procedure taught to them in a methodological training course arranged by the consultants that enabled them to express both valuation and uncertainty on the attributes identified in stage 1 in a format appropriate for input to stage 4.

The evaluation of the *product* rather than the *product- class* served as the basic unit in the evaluation of product-mixes and in the formation of company policy. Individual products could be adequately evaluated here because of the relatively small number of them in each of the four product classes. In all, 46 products were assigned for examination. This number did not comprise end products and packaging variants that had previously been represented in the product list of the company but that were currently withdrawn from production.

The principle underlying the selection of *experts* was that the products should be evaluated by the set of people with the most information available about the product or the given attributes. CW managers also served in this role here. Each expert was expected to provide only information concerning products or attributes in areas where he was competent. However, a significant demand for development of the methodology emerged from this. The problem of linking information resulting from the experts' individual sequences in the simulation model had to be solved.

The evaluation on each product on each of the main attributes was carried out on a scale ranging from 0 to 10, by a method involving credible interval estimation on the scale, with the simultaneous consideration of subattributes. Assigning a value of 10 on the scale meant that the given product fully met the requirements represented by the attribute (and those subattributes grouped under it), while 0 showed that the product did not meet the requirements at all. Each evaluator gave credible intervals expressed in terms of a center (most likely value) and lower and upper bounds. The uncertainty of the evaluator (characterizing his lack of information) was expressed by the length of the interval, while the center position in the interval was taken as his assessment of the product. In carrying out the procedure, the first step for the evaluator in considering each attribute was to choose best product and to place it at 10 (i.e., it defined the requirements to be met by the other products). The assessment of the other products on the scale was then carried out relative to the best product.

The examination of the products by the experts in this way was carried out over a period of one month.

Stage 4. Computation of Multiattribute Utilities of Products in the Mix

This was performed by the *consultant analysts*, using a multicriteria simulation model developed by Kiss et al. (Kiss 1978, Kiss and Török 1979), from a procedure proposed by Kahne (1975). The computations performed within the model resulted in three *separate* sets of rankings of the products evaluated in stage 3: one for each of the opinion groups whose attribute weighting vectors were assessed in stage 3. The consultants reported the assessment of each product in terms of how each of the three groups viewed it, according to the simulation model.

The computation was based on a multiattributed decision structure with judgments on individual attributes being represented by *intervals* instead of fixed values. The length of the interval was proportional to the uncertainty characterizing the opinion of the experts. The causes of uncertainty were

(i) lack of information available to individual evaluators concerning features of a product, and

(ii) differences in opinion between members of the group (which could be the consequence either of lack of information or of differing interests).

Thus the numerical judgments input to the computation were in fact "subjective" experts' estimates, controlled by similar estimates of other experts. That is why there was no exogenous principle that would be appropriate to determine "right" opinion or the "right" value within each interval. Accordingly, each point of the interval was regarded as being possible, and we used a random number generator (from a uniform distribution over the interval) to determine the concrete values needed in the individual steps of simulation.

After hundreds or thousands of iterations such steps in the simulation, each product under investigation could be characterized by a distribution function referring to the place of the product occupied in the overall ranking of the products on each attribute. The uncertainty of the judgment was expressed by the characteristics of the distribution. The structure of the model allowed us to determine the expectation values and the variance of the distribution characterizing each product on experts' views concerning the attribute.

The distributions on all attributes for each product were aggregated to give an overall distribution for the product. This aggregation was performed three times, the sets of attribute weights for each of the three groups identified above. In this way the computations of the model resulted in rankings based on the opinion of three different experts' groups (see Table 1) with each set of rankings accounting for the 10 main attributes simultaneously. Along with the position of the products in the three overall rankings the distribution for products on individual attributes produced by the computer program allowed us to discover the weak points of the products and to point out uncertainties and the differences of opinions. As an illustration, here is a report generated for a product on the basis of the procedure described above:

> "The product is in the first third of the ranking, its rank order numbers according to the weight of each of the three opinion groups are 10, 10, 11. According to the opinion of the group of top executives its profitability and up-to-dateness are very good, its market position and necessity for development are weak and average, respectively. In judging profitability the other two groups are of the same opinion. The product is seen by the third group to be well above average as far as up-to-dateness is concerned. Each group is rather uncertain concerning the profitability of the product, and the uncertainty expressed in the second group is greater than the average when judging the extent of necessity for development of production, man-power requirements and expressed uncertainty is greater than average. In the third group when judging up-to-dateness and importance."

Stage 5. Strategy Making

This stage was not covered by the DSS, as the decision makers did not wish the support of the analysts in this stage, and, on the other hand, analysts had no adequate method for strategy making in this case.

The problem defined at the start of the round by CW's director as that to be addressed by the MAU-P DSS was complete at stage 4, but it provided simulation outputs, not strategic prescriptions. In this sense the DSS supported *proposals*, rather than *decisions*. Vari and Vecsenyi (1982) discuss this as a pitfall of decision analysis: where the domain of the problem is greater than the domain of the decision analysis. In order to make decisions about the actual development strategies, additional criteria were used in this stage by the decisions makers (e.g., those relating to governmental programs, costs required for development, capacity constraints, etc.). Excluding these from explicit consideration within the MAU-P DSS meant that only part of the *decision makers'* values and preferences had to be made explicit and subjected to formal analysis which implicit values could be taken into consideration intuitively by the decision makers in arriving at the actual decision which was taken in stage 5.

In hierarchical decision-making systems, a partial analysis of the problem like that carried out in stages 1 to 4 supports the motivation of the lower level decision makers to *meet the expectations of higher- level decision makers*.

However, in ranking of the products and the characterization of the individual products provided by the DSS proved to be very useful for the company executives in forming strategic decisions, although they did not treat this information as prescriptive.

In the first step of strategic decision making, the production strategy was determined. Taking into account information concerning the ranking of the products it was decided which products were to be included or not into the production plan for the next few years. The detailed analysis of the existing products provided through the DSS prepared the way for the formation of the company's development strategy. In particular, the uncovering of the weak points of the products in the reports generated from the results of the DSS indicated the main directions for product development.

Consequently, the following development strategy was determined:

(i) Development can be and must be realized within a short period in the production of pesticides, herbicides and their intermediaries. (The most important of the pesticides identified for development were in the first quarter of the ranking of the products output from the DSS, while even the worst of them was placed in the middle of the rankings of 46 products, the kinds of intermediaries, identified as important for development were in the last third of the ranking. This fact can be accounted for by noting that they were currently at a pre-development stage.)

(ii) Development of those plastic products occupying the first place in the ranking to be maintained at the current level.

(iii) The production of any products currently produced in small volume, which are represented in the last third of the ranking is to be stopped until 1983.

This point, marking the end of the round, we reached six months after its start. It is, however, only one part of the strategy. The other part of the strategy concerns the evaluation of alternative R & D plans for those groups of projects identified above for further development. These are not considered in this report, as decision making in this report was not supported by the MAU-P DSS described here.

IV. CONSEQUENCES OF IMPLEMENTING A DSS IN ROUND 1

The results and methodological experiences acquired through the work carried out in Round 1 in implementing a DSS supporting decision making with the aim of modernizing CW's product-mix are as follows:

- The attributes identified in the literature on R & D policy making (OT-OMFB, 1978) were made easier to handle by the modifications and the working out of the system of criteria to be incorporated in the DSS.
- The way that the attributes were interpreted and discussed by the company executives and experts indicated that the consultants succeeded in their motivation to introduce modern approaches and methods of decision making into the company.
- Through developing and implementing a method for placing weights on criteria, it became possible to discover and describe their varying importance. In this method, the views of external experts and the value system of persons with influence on the company could also be taken into account.
- A unified approach to the tasks involved in product evaluation and knowledge of the techniques involved was achieved through the incorporation of a methodological training course.
- The examination of the products and strategic decision making has been transformed from disjunctive activities into a collective enterprise.

- A close linkage was established between executives and computer-based procedures in concrete (rather than purely formal) decision making activities.
- Through the use of the clustering techniques incorporated in the weighting procedure, together with the use of the simulation model in the preparation of the ranking of the products output by the DSS, information that was formerly obscured could be recognized (e.g., differences of similarities in value system of the different groups of evaluators, differing judgments of the products, and the uncertainties in experts' judgments, the weak points of the products).
- The systematic feedback of information concerning the results produced by the computer based techniques led to discussions and deeper analysis of key issues, thus offering new opportunities to confront and clarify differences in opinion and to form a collective value system appropriate for the formulation of policy.
- In exploiting the possibilities of collective work, an effective and fruitful interorganizational cooperation proved to be realizable.

V. ROUND 2

Nearly two years after the completion of the first round, CW's director requested the re-implementation of the DSS. Since stages and methods utilized in Round 2 were basically the same as those of Round 1, we will review here only the principal deviations and changes in the procedures in Round 2, compared with those implemented in Round 1.

A. Responsibility and Motivation of Parties Involved

The *decision makers'* motivation changed somewhat between the two rounds. Their need for justification of their decision-making at a higher level in the planning hierarchy had now decreased as the company's achievements had improved, removing the necessity for such justification. In Round 2, the principal motivation of the *decision makers* was now:

(i) to test their previous strategy by using new information based on the changed environment and internal situation of CW;

(ii) to make a new strategy taking into account the results of the DSS.

The motivation of the *experts* within the company did not alter significantly. It was interesting to note, however, that those experts who did not respond to the request to participate in the first round now wished to be included in the second round. This indicates the significance of the DSS (and participation in it) in organizational life within the company. The director also realized the importance of participation of middle-level managers and experts. This resulted in the participation of no less than 110 company executives and experts in Round 2. *External* experts were not, however, among these participants, for their good-will was won in the first round and so no requests were made for their participation in the second round. *The consultants* were motivated by the chance of being able to repeat the DSS in the same organization, and thus make improvements and comparisons.

B. Stages in the Analysis

The sequence stages of the analysis in Round 2 did not alter from that of Round 1 but the outputs of the individual stages differed from those of the first round.

Stage 1. Exploration of Attributes

Due to the experiences of the previous analysis as well as to the changes in the environment, the set of attributes defined in Round 1 were revised by company executives and experts.

This revision left the main attributes unaltered, however, it altered about 30% of the subattributes, and this in turn altered the precise definitions of the main attributes.

It is interesting to note that decision makers did *not* attempt to modify the set of main attributes to be incorporated in the DSS, even though, in formulating strategy in stage 5 of Round 1, other attributes had been taken into consideration in describing aspects of products. It appears they wanted once again to avoid the explicit incorporation of these latter attributes into a DSS.

Stage 2. Weighting of Attributes

The method of computing weights for attributes was similar to that used in Round 1, but the number of participant in the procedure increased from 63 to 110.

The value systems of the participants was revealed by the same clustering program employed in Round 1. Again, approximately 10 opinion groups were determined through the clustering procedure. After discussing these groups, it was agreed that the DSS model should consider the weights of the following six groups:

1. top managers (11 members)
2. market-oriented group (14 members ranking market situation in the first place
3. significance-oriented group (12 members ranking the significance of the product in the first place)
4. up-to-dateness-oriented group (10 members)
5. profitability-oriented group (a significant number of the participants, i.e., 41 members)
6. all participants

Groups 1 and 6 were defined *a priori*, the other four were selected opinion groups from the clustering procedure.

Table 2 shows the ranks of attributes according to these six groups of participants.

Stage 3. Assessment of the Alternative Products

There was a significant difference between the 1979 and 1981 production lists. In the meantime, the company had stopped manufacturing some items, and had initiated the development of some new products. The results of stage 5, Round 1, were partially responsible for these changes. While in the first round, 46 products had been considered alternatives, in Round 2, only 41 were considered.

Table 2. Ranking of attributes by the various groups.

Groups	Top managers 1	"Opinion groups" 2	3	4	5	All participants 6
Attributes						
E1	4	6	5	*1*	5	5
E2	3	4	*1*	4	4	3
E3	*1*	*1*	2	3	2	2
E4	6	5	6	5	6	6
E5	7	7	7	8	8	8
E6	5	3	3	6	3	4
E7	8	8	8	9	7	7
E8	10	10	10	10	10	10
E9	9	9	9	7	9	9
E10	2	2	4	2	*1*	*1*

Stage 4. Computation of Multiattribute Utilities of Products in the Mix

According to the assessment the products were divided into three groups. Since a product could only be allocated a maximum of 100, any product with a score above 60% could be regarded as outstanding. Those evaluated at between 40 and 60% would be average, while those under 40 could be regarded as weak.

On the basis of the ratings of the six "opinion groups" shown in Table 2, products were classified into three categories, giving the results summarized in Table 3.

Inspection of Table 3 reveals a slight tendency for the "significance-oriented" group (group 3) to rate relatively few products as outstanding, and to rate more products as weak. However, there is no significant difference in number of products rated as average across the groups.

Naturally, assessing individual products, there were some deviations between the ratings assessed by the various opinion groups, but these

Table 3. Assessment of products by the various groups.

Opinion groups		1	2	3	4	5	6
Number of products rated as:	Outstanding	11	9	5	9	10	9
	Average	19	21	21	20	22	22
	Weak	11	11	16	12	9	10
Total		41	41	41	41	41	41

differences were never significant. There were no occurrences where one group regarded a product as outstanding, while another group rated it as weak.

Stage 5. Strategy Making

In this stage, as in Round 1, formal procedures were not implemented to help decision makers in their strategy making activities. Instead, the output of the DSS implemented in this round (rankings of products) was used by CW's top managers to modify the strategy developed in stage 5 of Round 1. The precise nature of the other factor taken into account by their decision makers in revising CW's product mix development strategy is not known to us.

C. The Roles of the Parties Involved, Interfaces

Decision makers played an active role in the whole procedure of DSS, but they refused to use any formal analysis in the strategy making stage in both rounds.

Experts participated in adaptation and weighting of attributes and in the assessment of the products in terms of attributes.

Consultants had another role in the procedure. They catalyzed and organized the process and the activity of decision makers. They explored the attributes, while the decision makers and experts adapted them. They organized a training course for the participants on the methods of weighting attributes and assessment of the products and on the procedure of DSS. Consultants computed the weights of the attributes and the assessments of the products, while the weighting and assessment were made by the decision makers and the experts.

The *computer* was used in stage 3 for computing group statistics on weights and identifying the value systems of the decision makers and experts. It was used in stage 4 for multiattribute aggregation of data relating to assessment of the products and in computing the measure of uncertainty of each aggregated assessment. The computer was used only by the consultants; only the *results* of the computer based analysis were discussed with the decision makers and experts. The feedback and the discussion were part of the DSS procedure.

VI. CONCLUSIONS

The use of DSS was successful because

- actual decision makers participated in the whole procedure;
- actual decision makers were interested in the result of DSS;
- actual decision makers were the clients;

- tools and methods producing easily accessible results were used;
- a training course helped the application;
- previous knowledge possessed by experts could be utilized;
- in Round 1 approximately 70% and in Round 2, 90% of the managers participated (the higher the proportion who participate, the greater the likelihood of a successful application).

Effects of Changes Between Round 1 and Round 2

The change in decision makers' motivation for employing DSS was important for the consultants. In Round 1, the use of DSS was viewed by the decision makers as one of the tools of survival, but in Round 2, DSS was principally viewed as offering a good help for re-evaluating the product-mix R & D strategy developed in stage 5 of Round 1 using the results of the DSS implemented in Round 1.

The role of the training also changed since the first application of DSS. During the first round a 10-hour training course helped the decision makers and experts to learn the methods of weighting attributes and assessing the products and the procedure of DSS. As part of this course, the attributes were weighted and the results of aggregation were discussed. In Round 2 just four hours of training was found to be sufficient because the majority of the participants in the round were now familiar with the methods and use of DSS.

A change in the role of the consultants between Round 1 and Round 2 was observed. In the second round the decision makers and most of the experts had interiorized the procedure and so interactions with consultants were requested less frequently.

However, there was *no change in the pitfalls* offered by the problem to be analyzed. As pointed out in our discussion of Round 1, there was still a difference between the actual decision problem and the problem proposed for analysis.

In this case, the decision makers refused to use any formal analysis in strategy making in either rounds. However, the repeated use of DSS shows that, in spite of the limited decision problem to be involved by the formal analysis, decision makers could profit by it. Given the motivation of the decision makers in their conduct of stage 5 in both rounds, it appears that the DSS in this case met the goals of the decision makers through being perceived as a ***proposal support system*** (PSS; hence the emphasis on its simulation capability) rather than as a ***decision support system***. Understanding the role of the DSS here as a PSS avoids pitfall for decision analysis discussed above, this may have provided the key to its success.

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